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Municipal Landfill Gas Condensate

SCS Engineers, Inc., Reston, VA

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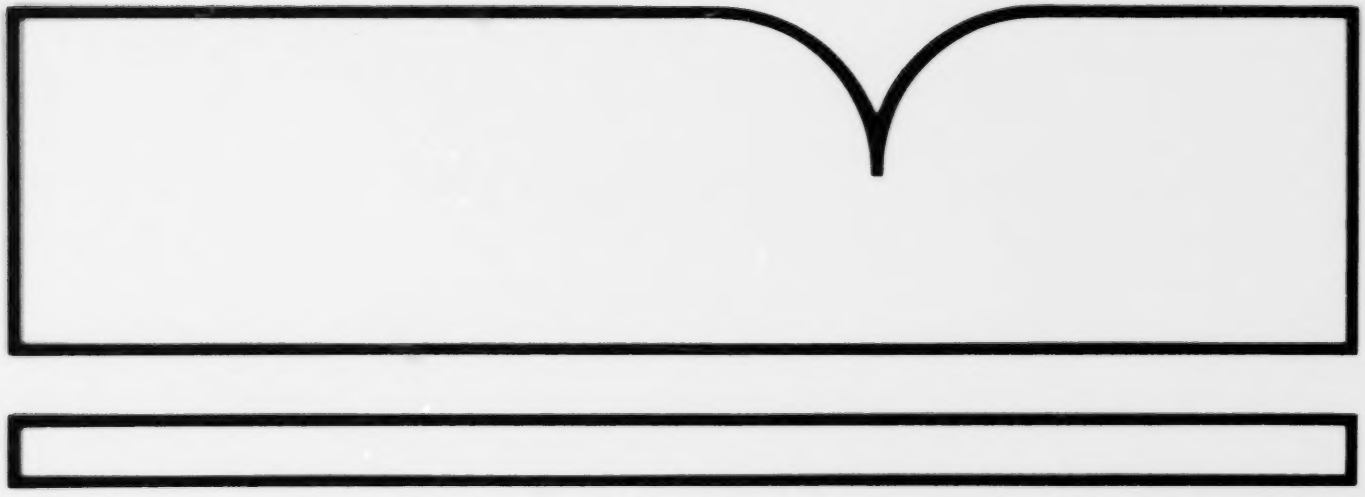

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MUNICIPAL LANDFILL GAS CONDENSATE

by

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11260 Roger Bacon Drive
Reston, Virginia 22090

Contract 68-02-3993

Project Officer
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16. ABSTRACT

New regulations relative to air emissions from municipal landfills may require the installation of gas collection systems at landfills. As landfill gas (LFG) is collected, water and other vapors in the gas condense in the system or are purposely removed in the normal treatment of the gas. Condensate production can amount to more than 5000 liters per day consisting of two liquid phases: an aqueous phase and a hydrocarbon phase.

This study involved the collection and analysis of condensate samples from four U.S. landfill sites with active gas mirgration or gas production systems. The characteristics of both the hydrocarbon phase and the aqueous phase of the condensate were compared against USEPA hazardous waste criteria. Results indicated that neither phase exhibited properties of corrosivity or reactivity. However, the hydrocarbon was ignitable, as was the aqueous phase in one sample. No pesticides, PCBs or priority pollutant metals were detected in any sample. A list was developed of 94 organic compounds found in LFG condensate, 49 of which are priority pollutant compounds.

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FORWARD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This document describes the chemical and physical characteristics of landfill gas (LFG) condensate from four operating LFG extraction systems and compares these charactistics to existing data. Three of the systems are designed for the recovery of LFG for sale as a fuel and one is designed to protect neighboring property from gas migration. The intended audience of this document includes those involved in the design of LFG collection systems and those involved in permit review of such systems.

For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

New regulations relative to air emissions from municipal landfills may require the installation of gas collection systems at landfills. As landfill gas (LFG) is collected, water and other vapors in the gas invariably condense in the system or are purposely removed in the normal treatment of the gas. Condensate production can amount to more than 5000 liters per day consisting of two liquid phases: an aqueous phase and a hydrocarbon phase. The management of landfill gas condensate continues to be problem for the solid waste landfill owner or operator because options for proper disposal are limited. Liquid disposal to solid waste landfills is virtually banned, and current regulations may identify condensate or one of its phases as a hazardous waste if it fails the TCLP Toxicity Test. EPA's Office of Solid Waste desired a baseline study to identify physical/chemical characteristics and hazardous properties of condensate from landfill gas collection systems at solid waste landfills.

This study involved the collection and analysis of condensate samples from four U. S. landfill sites with active gas migration or gas production systems. The characteristics of both the hydrocarbon phase and the aqueous phase of the condensate were compared against EPA hazardous waste criteria. Results indicated that neither phase exhibited properties of corrosivity or reactivity. However, the hydrocarbon phase was ignitable, as was the aqueous phase in one sample. No pesticides, PCBs or priority pollutant metals were detected in any sample. A list was developed of 94 organic compounds found in LFG condensate, 49 of which are priority pollutant compounds.

Most condensate samples obtained at the four sites were identified as hazardous according to the proposed regulatory limits of the TCLP Toxicity Test. Eleven compounds were present in the hydrocarbon phase at concentrations exceeding the proposed limits and five compounds exceeded the limits in the aqueous phase. However, the four sites varied considerably and definite correlations could not be made between site characteristics, the LFG collection systems, and the resultant condensate properties. It is possible that the low levels of organics found in the condensate from the aerobic LFG control site may result from the aerobic biodegradation of some of the compounds present. This correlation may be biased by other factors and should be tested by collection of data from more sites, both aerobic and anaerobic.

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INTRODUCTION

Landfill gas (LFG) condensate is a liquid produced in landfill gas collection systems. The condensate is removed as the LFG is withdrawn from landfills. Production of condensate may be through natural or artificial cooling of the gas or through physical processes such as volume expansion. Condensate is composed principally of water and organic compounds. Often the organic compounds are not soluble in water and the condensate separates into a watery (aqueous) phase and a floating organic (hydrocarbon) phase. This organic fraction may comprise up to five percent of the liquid.

The source of condensate is landfill gas, which is a mixture of gases produced by the biodegradation of organic materials within a landfill. Since oxygen from the air does not penetrate readily into a landfill, the community of microorganisms present in the waste is composed of specialized species that live only in anaerobic (no oxygen) conditions. Under these conditions they cooperate in the breakdown of organic molecules in the waste to release energy and carbon atoms for their own maintenance, growth, and reproduction. In the process, they release such waste products as methane, carbon dioxide, water, hydrogen, and intermediate breakdown products that they are incapable of further degrading. Under normal anaerobic conditions approximately equal volumes of methane and carbon dioxide are generated with trace amounts of other gases and volatile organic compounds (VOCs) in a gas mixture saturated with water vapor. In addition, other organic molecules from disposed solvents, or other wastes may be volatilized and enter the naturally produced LFG mixture. Because the gas is saturated, even inorganic ions may dissolve in the entrained liquid droplets present in the LFG and be carried along in the escaping gas. The metabolic activity (methanogenesis) that produces the methane also releases heat and typically landfill temperatures are 30 to 50 degrees C, promoting the vaporization of volatile and semivolatile compounds in the waste.

As LFG is extracted from a landfill and moves through the collection system, the gas cools and the various constituents condense out of the LFG. Much of the condensate may drain back into the landfill through the piping and extraction wells. The remaining condensable constituents of the gas must be removed by further treatment. When the gas reaches the first knock-out pot (separator) a sharp decrease in flow promotes further condensation of constituents and typically a mist eliminator helps remove the entrained liquid droplets from the gas. The liquid, which is a mixture of water and organic material, is collected for further treatment and/or disposal. Nothing is added to the gas stream to promote condensation so all constituents found in condensate originate in the landfill.

The methods of treatment or disposal depend on whether the condensate is considered hazardous or not. Under the original USEPA EP toxicity test and the California toxicity procedure, the condensate was not characterized as hazardous. Under the 1986 amendments to CERCLA, Section 124, (Superfund Amendments and Reauthorization Act- SARA) condensate from methane recovery and

recovery systems may be considered hazardous. If the aqueous or hydrocarbon phase of the condensate or any other waste material removed from the recovered LFG fails any of the four hazardous characteristics identified under RCRA Subtitle C (Section 3001), then the condensate phase or other waste material is considered a hazardous waste and its management and disposal is regulated accordingly.

The hazardous characteristics identified under Section 3001 include:

- Ignitability
- Corrosivity
- Reactivity
- TCLP Toxicity

The EP Toxicity test was replaced with the EP III Toxicity test. In these tests, if the liquid separates into two phases, the concentrations of the listed toxicants are reported as the simple weighted average of their concentrations in each phase. This can have an impact on the owner/ operators of sites that produce condensate composed of two phases. If the aqueous phase were considered non-hazardous while the organic phase was not, a literal interpretation of this rule might result in all of the condensate being classified as hazardous rather than the small percent comprising the organic phase.

EPA has proposed to amend the EP Toxicity Characteristics (FR V. 51, 114. June 13, 1986) by: (1) expanding the characteristic to include 38 additional compounds (52 total); (2) applying compound-specific dilution/ attenuation factors generated from a ground-water transport model, and; (3) introducing a second generation leaching procedure, the Toxicity Characeristic Leaching Procedure (TCLP). This report will evaluate the characteristics of LFG condensate according to these proposed changes.

There is increasing concern with the surface emissions of LFG from landfills and their contribution to air pollution. The most efficient way that these emissions can be reduced is by use of LFG recovery techniques. The benefits of reduced air pollution and increased alternative energy supplies need to be weighed against the total costs of the needed recovery systems. Condensate is a natural by-product of LFG collection and must be included in any cost/benefit analysis. If the recovery of LFG at a site is profitable it can help defray the expenses of closure and post-closure care at the landfill.

The purpose of this project was twofold: (1) to review existing background information on the characteristics of condensate; and (2) to obtain and analyze condensate samples from LFG collection systems at four landfills nationwide. The condensate samples were to be sampled and analyzed under prescribed conditions in order to qualitatively and quantitatively describe condensate characteristics. Specifically, the analyses were to determine baseline properties of LFG condensate from a limited number of samples and establish if either condensate phase is hazardous, and if so, on the basis of which constituents. In addition, LFG collection system information was collected to assess possible impacts due to system operations.

CONCLUSIONS

This research investigation obtained and analyzed condensate samples from selected nationwide landfill sites with operating LFG collection systems. Due to an absence of published literature on condensate, this work serves as a baseline effort to identify condensate characteristics. Conclusions and recommendations from this investigation are based on a limited sampling program that indicates that site-specific variability is to be expected. However, they are presented below as guidance to landfill owner/operators, landfill design engineers and regulatory agencies for implementing practical measures to collect and properly dispose landfill gas condensate.

1. Landfill gas condensate is a two-phase liquid containing an aqueous phase and an organic phase (which often separates as a float). The organic phase portion varies from site to site, and may range from less than one percent to five percent (by volume) of the total mixture. In general, the aqueous phase is mostly water and trace organic compounds. The organic phase consists principally of hydrocarbons, xylenes, chloroethanes, chloroethenes, benzene, toluene, and trace moisture.

2. Condensate production from three sites with landfill gas recovery systems ranged from 44 to 162 liters generated per 1,000 cubic meters of unprocessed landfill gas.

3. Condensate quality, as measured by standard wastewater analyses (e.g., BOD, TOC, COD, etc.) varies among sites and is similar to typical landfill leachate.

4. The major organic components of landfill gas condensate were identified using standard EPA analytical methods for priority pollutants in water samples. The frequency of detection and concentrations were compared to regulatory levels in the proposed TCLP Toxicity Test. Of the 49 priority pollutant compounds detected in condensate, 15 are listed with their regulatory levels in the proposed TCLP contaminants list. Ten VOCs and three acid and base/neutral priority pollutants were found in condensate at levels exceeding the proposed regulatory limits.

5. Condensate quality, as measured by the organic priority pollutants present, differs according to each phase (i.e., aqueous versus organic) and the type of priority pollutant (VOCs versus acid and base/neutral fractions). Similar VOCs are found in both the aqueous and organic phases; however, a larger number of acid and base/neutral compounds are present in the aqueous than in the organic phase of the condensate. Concentration levels may be orders of magnitude higher in the organic phase than the aqueous phase.

6. Based on hazardous characteristics tests for ignitability and TCLP toxicity, landfill gas condensate, and particularly the organic phase, may be a hazardous waste. Eleven priority pollutants were detected in the organic phase at levels that exceed the proposed regulatory limits.

7. Landfill gas condensate samples from the four sites contained no pesticides, PCBs, or priority pollutant metals and did not exhibit hazardous characteristics when tested for corrosivity or reactivity.

RECOMMENDATIONS

1. Data from this limited study and other literature sources indicate much diversity in the constituents found in landfill gas condensate. The composition is likely influenced by many site-specific variables (such as refuse moisture content, waste composition, temperature, gas collection rate, and other system design features) that were beyond the scope of this investigation. Future field testing efforts should include a sufficient number of samples at 20 to 30 nationwide LFG collection sites to help determine the key environmental and design variables that affect condensate composition.

2. This study was directed principally towards identifying the priority pollutants present in condensate. Future analytical efforts should fully characterize LFG condensate and in particular, the organic phase, for other (i.e. nonpriority pollutants) organic and inorganic constituents.

3. Analytical problems experienced on the oil-like organic phase caused by the complicated matrix suggests the need for analytical protocol development and testing.

4. Regulatory decisions regarding disposal of landfill gas condensate may depend on the composition and quantities produced in the numerous landfill gas collection (recovery and migration control) systems operating throughout the country. Specifically, whether or not condensate must be treated and disposed as a hazardous waste may impact available capacity for treatment and the economic viability of gas recovery systems. Further studies should address the nature and extent of these impacts.

LITERATURE REVIEW

There is little published information on the characteristics and quantities of condensate produced in landfill gas collection systems. While it is likely that some owner/operators of LFG collection systems have performed sampling and analysis of condensate, these results remain unpublished. Limited historical data on condensate characteristics were available for compilation from sampling and analytical projects conducted by SCS Engineers and from other unpublished sources. At several sites, landfill owners/operators released information only when promised anonymity.

Historical data from nine landfills in six states were assembled and reviewed from various analytical reports. One to five condensate samples were reported for each landfill, resulting in a total of 24 samples. Limited or no information was provided about the condensate samples with regard to sampling techniques, analytical procedures, or observations. For example, analyses of five samples taken from one landfill were conducted only on the organic phase, and at another site, only the water phase was analyzed. Generally, detailed procedures were not reported for the other samples, thus it is assumed that no special steps were taken to separate the specific phases of the condensate. Consequently, it should be recognized that the historical data may not be directly comparable. Nevertheless, the historical data provided herein do provide useful guidelines on general characteristics of condensate found in LFG collection systems.

Condensate samples were analyzed for typical wastewater parameters, priority pollutants (metals and organics), other organics, and one hazardous waste characteristic (ignitability). Each of the landfill sites has been identified below only by state location (e.g., New York) to assure anonymity. Each state and its associated condensate samples has been grouped into a general climatic (i.e., temperature) region, and presented accordingly in Tables 1 and 2, respectively. Condensate samples taken from each landfill site are described briefly below.

SITE A

Two condensate samples were collected at this New York landfill. One sample showed the presence of chlorobenzenes and alkylbenzenes (including xylenes), while the other contained chloroethenes and methylene chloride. Both samples contained phenol. Furthermore, both samples were found to have high levels of BOD, COD, and TOC, low ph, high oil and grease content, and only one had high ignitability.

SITE B

The sample taken at this New York site contained acetone, benzene, methyl ethyl ketone (MEK), carbon disulfide, toluene, and isobutanol. It also contained ethers, methyl isobutyl ketone (MIK), C7 and C8 hydrocarbons, trimethyl

TABLE 1. HISTORICAL LANDFILL GAS CONDENSATE ANALYSIS DATA - COOL REGIONS OF THE UNITED STATES

Measured parameter	Site/ Sample A1	A2	B	C1	C2	C3	C4	C5	D1	D2	D3
WASTEWATER PARAMETERS: (typical strengths)											
BOD (100 to 500 mg/l)	9300	2300									
COD (250 to 1000 mg/l)	14720	5340							2856		
TOC (100 to 300 mg/l)	4900	2700							575		
Cl- (30 to 100 mg/l)	7									1	0.5
Total Carbon (mg/l)									740		
Tot. Inorg. Carbon (mg/l)									165		
TSS (mg/l)			.0024(a)								
TDS (mg/l)			.33(a)								
TS (mg/l)			.34(a)						17	96.4	14.4
VS (mg/l)											
Oil and Grease (mg/l)	180	110									
MAJOR IONS (mg/l):											
SO2-										1	1
SO4-	25	18									
Sodium											
Potassium											
Calcium											
Magnesium											
Iron											
Manganese				0.21(d)	0.21(d)	0.039(d)	0.21(d)	.05(d)			
HAZARDOUS CHARACTERISTICS:											
Ignitability	>185F	84F									
Corrosivity (pH)	3.7	3.2	8.2						4.6	6.6	6.1
PRIORITY METALS (mg/l):											
Arsenic			.011(b)	*	*	*	*	*			
Cadmium				.089(d)	.044(d)	.02(d)	.044(d)	.016(d)			
Chromium			.03(b)	.8(d)	.46(d)	.27(d)	.46(d)	.19(d)			
Copper											
Lead			*								
Mercury			*	*	*	*	*	*			
Nickel				.25(d)	.056(d)	.035(d)	.056(d)	.027(d)			
Selenium			*								
Silver			.02(b)								
Zinc											

(Continued)

TABLE 1. (CONTINUED)

Measured parameter	A1	A2	B	C1	C2	C3	C4	C5	D1	D2	D3
VOLATILE ORGANICS (ug/l):											
Acetone			73(c)								
Benzene			2(c)	3030(d)		3165(d)	4035(d)	2340(d)			
2-Butanone(MEK)			12(c)								
Carbon Disulfide			78(c)								
Chlorobenzene				19150(d)	2400(d)	21600(d)	21200(d)	18450(d)			
Chloroethane											
1,2-Dichlorobenzene		108		545(d)(e)	605(d)(e)	435(d)(e)		545(d)(e)			
1,3-Dichlorobenzene											
1,4-Dichlorobenzene											
1,1-Dichloroethane											
1,2-Dichloroethane				100(d)		105(d)	160(d)	70(d)			
1,1-Dichloroethene				43200(d)		35800(d)	40800(d)	27650(d)			
trans-1,2-Dichloroethene	130										
1,2-Dichloropropane											
Ethyl Benzene		280									
Methylene Chloride	600										
4-Methyl-2-Pentanone(MIK)											
Tetrachloroethylene	2			1650(d)		2100(d)	2200(d)	1200(d)			
Toluene	560	790	8(c)	81050(d)	36750(d)	86800(d)	86900(d)	72800(d)			
1,1,1-Trichloroethane											
Trichloroethene				650(d)		885(d)	925(d)	480(d)			
Vinyl Chloride											
ACID FRACTION (ug/l):											
2-Chlorophenol											
2,4-Dimethylphenol											
4-Nitrophenol											
Phenol											
BASE/NEUTRAL FRACTION (ug/l):											
Acenapthylene											
Bis(2-Ethylhexl) Phthalate											
Diethyl Phthalate											
Di-n-Butyl Phthalate											
Fluorene											
Hexachloroethane											
Isophorone											
Naphthalene											
Nitrobenzene											
N-Nitrosodi-n-Propylamine											
Phenanthrene											
1,2,4-Trichlorobenzene											

(Continued)

TABLE 1. (CONTINUED)

Measured parameter	A1	A2	B	C1	C2	C3	C4	C5	D1	D2	D3
OTHER COMPOUNDS (ug/l):											
Xylenes	140	840		32700(d)	28050(d)	34450(d)	35700(d)	32250(d)			
Tetrahydrofuran											
Isopropanol											
2-Butanol											
n-Propanol											
Methyl Acetate											
Ethyl Acetate											
cis-1,2-Dichloroethylene											
Methyl Propionate											
Isobutanol			11(c)								
n-Butanol											
Isopropyl Acetate											
Methyl Buryrate											
Isobutyl Acetate											
Propyl Acetate											
Ethyl Butyrate											
Propyl Propionate											
Butyl Acetate											
Methyl Valerate											
Propyl Butyrate											
Butyl Propionate											
1-Methylpropyl Butyrate											
Butyl Butyrate											
1-Methyl-4-Isopropyl-7-Oxabicyclo--[2,2,1] Heptane											
Cineol											
Fenchone											
C9H12 Aromatic Hydrocarbons											
Diethyl Ether			14(c)								
3-Methyl-2-Butanone			21(c)								
C7 Hydrocarbon			5(c)								
C8 Hydrocarbon			7(c)								
1,3,3-Trimethyl-2-Norbornanone			8(c)								
Camphor			29(c)								

(a) % by weight
(b) ppm by weight
(c) ppb by weight
(d) ppm in hydrocarbon Phase
(e) Isomer not specified
(*) Below detection level for metals

TABLE 2. HISTORICAL LANDFILL GAS CONDENSATE ANALYSIS DATA - WARM REGIONS OF THE UNITED STATES

Measured parameter	Site/ Sample E1	E2	E3	F1	F2	F3	F4	G1	H	I1	I2	I3	I4
WASTEWATER PARAMETERS :													
(typical strengths)													
BOD (100 to 500 mg/l)									>1000		23750	31250	
COD (250 to 1000 mg/l)						476		6350	1023				
TOC (100 to 300 mg/l)									1600				
Cl- (30 to 100 mg/l)								79					
Total Carbon (mg/l)													
Tot. Inorg. Carbon (mg/l)													
TSS (mg/l)									11.4		1803	82	
TDS (mg/l)									25			2415	
TS (mg/l)								36.4					
VS (mg/l)												1085	
Oil and Grease (mg/l)						3.2		30	10.5				
MAJOR IONS (mg/l):													
SO2-									7.01				
SO4-								29					
Sodium									1.1				
Potassium									0.81				
Calcium									1				
Magnesium									0.08				
Iron									0.1				
Manganese													
HAZARDOUS CHARACTERISTICS:													
Ignitability		>140F											
Corrosivity (pH)						3.4		3.6	3.17	3.5	3.5	3.5	3.5
PRIORITY METALS (mg/l):													
Arsenic	10	80	10						*	*	0.069	0.194	0.0065
Cadmium	*	*	*						*	*	6.32	0.094	0.93
Chromium	20	170	10						*	*	0.034	0.011	0.064
Copper	90	380	90						*				
Lead	20	10	20						*	*	0.034	0.085	0.071
Mercury	*	*	*						*	0.034	0.0065	0.00069	0.0056
Nickel	*	*	*						0.1				
Selenium	*	*	*						*	*	0.01	0.017	0.018
Silver	*	*	*										
Zinc	300	370	330						0.14	*	1.24	1.25	0.806

(Continued)

TABLE 2. (CONTINUED)

Measured parameter	E1	E2	E3	F1	F2	F3	F4	G1	H	I1	I2	I3	I4
VOLATILE ORGANICS (ug/l):													
Acetone									4600				
Benzene	183	51	71										160
2-Butanone(MEK)									8600				
Carbon Disulfide	3	1	1										
Chlorobenzene	10	6	10						41				
Chloroethane	588		133							60	710	32	37
1,2-Dichlorobenzene										350	385		
1,3-Dichlorobenzene	20	14	10								350	256	240
1,4-Dichlorobenzene	22	9	8										
1,1-Dichloroethane	1		6										
1,2-Dichloroethane		2											
1,1-Dichloroethene	44	35	143	1.4	14								
trans-1,2-Dichloroethene	1		1						19		575		
1,2-Dichloropropane	70	108	425	5.1	10					250		375	
Ethyl Benzene	41	17	27	5.8	91	1.4	19.5		4600	775	400	2900	450
Methylene Chloride									1100				
4-Methyl-2-Pentanone(MIK)	5	22	32		20	11.2	13.4			475	250	1130	150
Tetrachloroethylene	642	251	442	8.8	100					2875	1050	6200	1375
Toluene						2							
1,1,1-Trichloroethane	6	3	8		7	4.8	4.1			1400	450	3700	725
Trichloroethene	7	7	4	1.4	5.4								
Vinyl Chloride													
ACID FRACTION (ug/l):													
2-Chlorophenol	5400	6600	1300										
2,4-Dimethylphenol	645	549	752										
4-Nitrophenol										14	136	20	160
Phenol												12	
										16	420	720	760
BASE/NEUTRAL FRACTION (ug/l):													
Acenapthylene													
Bis(2-Ethylhexl) Phthalate										10	13		
Diethyl Phthalate										28	29	18	48
Di-n-Butyl Phthalate										21			28
Fluorene										33	3	67	28
Hexachloroethane	93		84							9	17	10	3
Isophorone	23												
Naphthalene	13		295							776	836	296	1568
Nitrobenzene	142		150							220	369	160	143
N-Nitrosodi-n-Propylamine											217		
Phenanthrene										15	115	38	
1,2,4-Trichlorobenzene	62		72							6			
										57	120	56	18

(Continued)

TABLE 2. (CONTINUED)

Measured parameter	E1	E2	E3	F1	F2	F3	F4	G1	H	I1	I2	I3	I4
OTHER COMPOUNDS (mg/l):													
Xylenes	259	166	236						120				
Tetrahydrofuran									2100				
Isopropanol									40000				
2-Butanol									30000				
n-Propanol									3000				
Methyl Acetate									1000				
Ethyl Acetate									1000				
cis-1,2-Dichloroethylene									65				
Methyl Propionate									500				
Isobutanol									200				
n-Butanol									10000				
Isopropyl Acetate									90				
Methyl Buryrate									500				
Isobutyl Acetate									60				
Propyl Acetate									200				
Ethyl Butyrate									700				
Propyl Propionate									60				
Butyl Acetate									200				
Methyl Valerate									40				
Propyl Butyrate									200				
Butyl Propionate									40				
1-Methylpropyl Butyrate									60				
Butyl Butyrate									200				
1-Methyl-4-Isopropyl-7 -Oxabicyclo-[2,2,1] Heptane									50				
Cineol									400				
Fenchone									100				
C9H12 Aromatic Hydrocarbons									200				
Diethyl Ether													
3-Methyl-2-Butanone													
C7 Hydrocarbon													
C8 Hydrocarbon													
1,3,3-Trimethyl-2 -Norbornanone													
Camphor													

(a) % by weight
(b) ppm by weight
(c) ppb by weight
(d) ppm in hydrocarbon Phase
(e) Isomer not specified
(*) Below detection level for metals

As, Cr, and Ag. The pH of the sample was 8.2; total suspended solids (TSS), total dissolved solids (TDS) and total xylene (TX) contents of the sample were low.

SITE C

Five samples were taken at this Illinois site. Analyses were performed only on the hydrocarbon phase. All five samples showed high concentrations of chlorobenzene, toluene, and xylenes. Four out of five samples showed high concentrations of chloroethenes and benzene and also indicated the presence of 1,2-dichloroethane and trichloroethene. All five samples contained Cd, Cr, Ni, and Mn at low levels.

SITE D

The three samples taken at this Kentucky site were analyzed for wastewater parameters only. COD and TOC contents were found to be slightly higher than typical values reported for domestic sewage.

SITE E

All three samples taken from this Florida landfill consisted of the water phase; no hydrocarbon phase was present during sampling. All of the samples showed the presence of benzene and its chloro and alkyl derivatives, chloroethenes, methylene chloride, chlorinated alkanes, toluene, and vinyl chloride. Furthermore, all three samples revealed high concentrations of chlorophenols and alkylphenols. Isophorone was found in one sample only, while naphthalene and nitrobenzene were found in two of the three samples. All three samples showed high concentrations of As, Cr, Cu, Pb, and Zn.

SITE F

Four samples were taken at two different locations of this Florida landfill (two from each location). All of the samples showed the presence of chlorinated alkenes. Only one location showed the presence of ethylbenzene, toluene, and vinyl chloride. The levels of wastewater parameters (e.g., COD, oil and grease), were found to be in a range typical for domestic sewage. The pH of the sample was 3.4.

SITE G

One sample was taken at this California site. COD content in the sample was found to be more than 10 times that of typical domestic sewage COD content. Chloride, sulfate, and oil and grease levels were low.

SITE H

The sample taken from this California site showed high concentrations of acetone, MEK, MIK, and methylene chloride. Chlorobenzene and dichloroethene were found in small concentrations. In addition, the sample contained

xylenes, furans, different alcohols, carboxylates, diethyl ether, cineol, fenchone, trimethyl norbornanone, and C9H12 hydrocarbons. Heavy metal analysis indicated the presence of only Ni and Zn at trace levels. TOC concentrations were up to five times higher than typically found in domestic sewage, while the concentrations of other wastewater parameters were within the ranges reported for domestic sewage.

SITE I

Condensate samples were collected at four locations in the gas recovery process of this California site. Visual inspection and overall appearance of these samples suggested the presence of high concentrations of organic components.

All four samples were found to contain significant amounts of toluene, chlorozenzenes and alkylbenzenes, phenols and alkylphenols, and chloroethenes (including trichloroethylene (TCE) and tetrachloroethylene). Isophorone, dichloromethane, and naphthalene were also identified at significant levels. Relatively low levels of phthalates were identified and quantified. In addition, the samples indicated the presence of acenaphthylene, n-nitrosodipropylamine, and phenanthrene. The results of trace metal analyses showed the presence of As, Cd, Cr, Pb, Se, and Zn in three samples, and Hg in all four samples.

Some physical parameters related to the biological and organic content of the liquid were also measured: BOD, COD, dissolved solids, and volatile solids. BOD was found to be about 100 times as high as typical domestic sewage values.

SUMMARY RESULTS

Wastewater Parameters

Wastewater parameters were measured in samples from seven landfills (A, B, D, F, G, H, and I). BOD was measured in samples collected from landfills A, H, and I. In all of these samples, BOD was found to be much higher than the reported average values for domestic sewage but within the range for leachate. COD was measured in samples from landfills A, D, F, G, and H; it was found to be higher than the reported domestic sewage values in samples from three landfills (A, D, and G), and within the domestic sewage concentration range in the samples from two landfills (F and H). TOC was measured in samples from three landfills (A, D, and H). All of the samples contained levels of TOC higher than reported typical domestic sewage values. Both BOD and TOC levels were similar to those of leachate. Total carbon and total inorganic carbon were reported only in the samples from landfill D and were found to be low. The values of BOD, COD, and TOC from the nine sites are compared to typical sewage and leachate values below:

Parameter	Condensate Range (mg/l)	Domestic Sewage (mg/l)	Typical Leachate (mg/l)
BOD	1,000 - 31,250	100 - 500	1,050-32,400
COD	476 - 14,720	250 - 1,000	800-50,700
TOC	575 - 4,900	100 - 300	700-68,000

The remaining parameters analyzed within this group were chloride, sulfate, sulfide, TSS, TDS, TS, VS, oil and grease, and major cations. All of the values were found to be low, except for the TSS, TDS, and VS contents of the condensate from site I. Most other wastewater parameters including solids, oil and grease, and major cations were found to be lower than for domestic sewage.

Hazardous Waste Characteristics

Of the four hazardous characteristics (i.e., ignitability, corrosivity, reactivity, and EP toxicity), ignitability was the only parameter measured. Three samples were tested for ignitability. One was found to be ignitable and two were not (Tables 1 and 2). The hydrocarbon phase samples from site C were not tested for this characteristic.

Although corrositivity tests were not reported, pH can be used as a guide as to whether or not a material is corrosive. The range of pH measurements was 3.17 to 8.2, with nine samples between 3.17 and 3.7 and four samples between 4.6 and 8.2. A pH of 2 and below or 12.5 and above would fail the EPA corrosivity test. Thus, none of the samples were hazardous on the basis of corrosivity.

Priority Pollutant Metals

Condensate samples from five landfills (B, C, E, H, and I) were analyzed for priority pollutant metals. Ten metals were found: As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, and Zn. As and Zn were found in samples from three landfills; Cd, Ni, and Pb were found in samples from two landfills; Cr was found in samples from 4 landfills; and Cu, Hg, Se, and Ag were each found in samples from one landfill. There appears to be no correlation of metal ions in condensate with climatic region.

Priority Pollutant Organics

Condensate samples from seven landfills (A, B, C, E, F, H, and I) were analyzed for priority pollutant organics. A total of 38 compounds was quantified. Condensates samples from six landfills contained chloroalkenes and toluene; those from five landfills contained chlorobenzenes; and condensates from four landfills contained benzene , alkylbenzenes , and methylene chloride

Chloroalkanes were found in condensates from three landfills ; and MEK, acetone, alkylphenols, isophorone, and naphthalene in samples from two landfills. Chlorophenol, nitrophenol, phenol, carbon disulfide, acenaphthalene, phthalates, fluorene, nitrododi-n-propylamine, and phenanthrene were each found in samples from only one landfill. There is no climatic trend evident in the priority pollutant organic data. The hydrocarbon phase from site C has significantly higher concentrations of VOCs than any of the aqueous phase samples from other sites.

Other Organic Compounds

Xylenes were found in four out of seven landfills . A number of alcohols and acarboxylates was analyzed and detected in condensate from one landfill (H). The same landfill condensate also contained xylenes, diethyl ether, MIK, furans, cineol, fenchone, C7 and C8 hydrocarbons, C9H12 aromatic hydrocarbons, trimethyl norbornanone, and camphor. Isobutanol was also detected in the condensate sample from site B. Xylenes were a major component in the organic phase samples from site C.

METHODS AND MATERIALS

SITE SELECTION

Landfill sites for condensate sampling were chosen on the basis of size, geographic location, and cooperation of the site owners/operators. The sites chosen had to be of sufficient size to produce several hundred gallons of condensate per day to insure representative samples of newly formed condensate. Landfill sites with either gas control systems or gas production systems were considered for selection to note any differences. Similarly, it was desirable to consider sites that contained only municipal refuse versus those sites that combined municipal and commercial waste. It has been shown that refuse moisture content has a significant effect on LFG generation rates (SCS Engineers, Walsh and Stamm, 1986). Thus, it was desirable to compare sites from moist climates with those from dry climates.

Finally, landfill sites were selected based on the owners/operators willingness to allow site access and supply background information on site development and operation. In several cases, site access was simply denied. Site access through other landfill owners was unsuccessful, likely due to the current uncertainty in the regulatory climate relative to condensate and its disposal. Those owners who did agree to participate, did so with the understanding that their sites would not be identified. In addition, the details of the systems used to extract and treat the gas are considered proprietary information. Those companies engaged in gas production are more stringent in this regard than those operating gas protection (control) systems.

By September 1986, four landfill sites were selected which met the above conditions and where site access was provided for a one-day sampling program. Three of the sites had gas recovery systems for processing and ultimate sale for production purposes and the other had a gas collection system for purposes of methane migration control.

SAMPLING PROCEDURES, SAMPLE PRESERVATION AND HANDLING

LFG condensate was sampled from fresh accumulations in closed storage containers or directly from the gas collection pipelines. Three production and one migration control system were sampled. All samples were taken under vacuum from the last point in the system prior to treatment, processing, or blower equipment. This was the "knock-out" pot storage tanks at the production sites and from a low point in the collection system pipe at the control system. All samples were fresh and volatilization of trace organics was minimized during sampling. All samples were taken in duplicate or triplicate and deionized water was used for field blanks.

The samples were taken by free-catch directly into the sample containers from the sampling port. At the Northeast site, the sample was taken by gravity flow from a drainage valve at a low point in the collection header pipe. At the Midwest site and the southern California site, the condensate was pumped from underground storage tanks. Both sites had phase separators with the aqueous and hydrocarbon phases stored in separate tanks. Both phases were collected at the southern California site, but access to only the aqueous phase was given at the Midwest site. At the northern California site, the two phases were stored in above ground tanks and the collection of samples was by gravity flow through valves in the phase separation tank. Samples for analysis of organic compounds were collected in amber glass bottles. Samples for VOC analysis were collected in special sealing VOC vials. All other samples were collected in polyethylene containers. All samples were sealed and shipped with chain-of-custody documents in iced shipping containers directly to the laboratories. This was done using overnight express except for the southern California samples, which were hand delivered directly from the site to the laboratories. A detailed description of these procedures is contained in the approved Quality Assurance Project Plan (QAPP).

ANALYTICAL PROCEDURES

Analyses of condensate were performed using EPA Standard Methods for hazardous characteristics, priority pollutant metals (EPA SW-846), priority pollutant organic compounds, (EPA 624 and 625), and pesticides (EPA 608). Conventional wastewater parameters were also measured using Standard Methods, 16th Ed. (1985). BOD (Standard Method 507, pg. 525); COD (Standard Method 508, pg. 532); TOC (Standard Method 505A, pg. 507); pH value (Standard Method 423, pg. 429); nitrate nitrogen (Standard Method 426C, pg. 467); and hydrogen sulfide (Standard Method 427B, pg. 467). Duplicates, spikes and surrogates were used to determine precision and accuracy of the analyses. Field blanks were analyzed and any compounds detected were subtracted from the sample results and the difference reported. The GC/MS analyses were performed with a

Hewlett Packard GC/MS 5995 with a HP1000 data system using a packed column of 1 percent SP-1000 on 60/80 carbopack B. A full description of all methods, materials, equipment, spikes, and surrogates used in the analyses is contained in the QAPP.

RESULTS AND DISCUSSION

SITE CHARACTERISTICS

Site information was obtained from the four landfill sites selected for LFG condensate and gas sampling. As shown in Table 3, these sites are designated as "Northeast", "Midwest", "Northern California", and "Southern California", representing general climatic regions of the United States. The first two sites are in cool moist climatic zones in the Northeast and Midwest where freezing temperatures occur regularly in winter and the annual precipitation of about 1016 mm (40 inches) is spread evenly through the year. The second two sites are in warmer climate regions in coastal California. The site in Northern California rarely experiences freezing temperatures and has about half the annual precipitation of the first two sites. The southern California site almost never experiences freezing temperatures and receives about one fourth the precipitation of the first two sites. The major California precipitation occurs from November through March with the summers hot and dry.

Table 4 presents detailed site information for each of the four sites. The Northeast site is an active site with a gas migration control system. It is composed of about 12 hectares (30 acres) of municipal refuse up to 36 meters high with about 50 percent of the area developed for LFG collection. About 61,000 cubic meters of LFG with a 22 percent methane is collected and flared. An unknown quantity of condensate is collected. The condensate is composed of one phase and combined with leachate for treatment.

The Midwest site is a closed landfill with a gas production system. It is composed of about 36 hectares (90 acres) of municipal and commercial waste up to 15 meters high with 100 percent of the area developed for LFG collection. The LFG collected has a methane content of 63 percent. The operation generates about 4,260 liters of aqueous condensate each day which is treated and disposed in the sewer. The hydrocarbon phase makes up about 0.5 percent of the condensate and is separated and disposed by incineration.

The Northern California site is closed and accepted both municipal and commercial wastes while active. It covers about 37 hectares (92 acres) filled as high as 23 meters above the surrounding area with about 75 percent of the area developed for LFG collection. It is a gas production system collecting LFG with a methane content of 59 percent. The operation generates about 2,710 liters of condensate per day with about 0.5 percent hydrocarbon phase. The aqueous phase is treated and sewered and the hydrocarbon phase sold.

TABLE 3. SUMMARY OF CLIMATIC DATA FOR THE FOUR SAMPLED REGIONS (1985)**

	NORTHEAST	MIDWEST	N. CALIFORNIA	S. CALIFORNIA
JANUARY				
Temp	28.8	17.5	42.2	54.3
Dev***	-2.5	-5.1	*	-0.9
Precip.	1.06	1.31	0.76	0.91
Dev	1.87	-0.51	*	-2.07
Cooling Degree Days	0	0	0	0
FEBRUARY				
Temp	34.8	23.8	51.1	56.1
Dev	2.3	-3.4	*	-0.5
Precip.	2.13	2.95	2.10	1.58
Dev.	-1.07	1.44	*	-0.92
Cooling Degree Days	0	0	0	0
MARCH				
Temp	45.1	41.4	51.4	56.2
Dev	5.1	4.4	*	-1.7
Precip.	2.17	4.73	3.68	0.61
Dev	-1.82	1.96	*	-1.08
Cooling Degree Days	0	0	0	0
APRIL				
Temp	54.2	54.4	62.0	62.7
Dev	3.9	4.7	*	1.8
Precip.	2.12	2.45	0.04	0.00
Dev	-1.64	-1.57	*	-0.83
Cooling Degree Days	10	53	22	24
MAY				
Temp	63.1	63.5	62.7	63.5
Dev	3.4	3.0	*	-0.8
Precip.	4.77	3.06	0.03	0.21
Dev	1.37	-0.18	*	0.05
Cooling Degree Days	44	72	31	15
JUNE				
Temp	68.4	67.8	73.1	69.5
Dev	-0.6	-2.8	*	1.3
Precip.	4.56	1.93	0.08	0.00
Dev	1.58	-2.07	*	-0.04
Cooling Degree Days	126	140	260	149
JULY				
Temp	74.8	74.7	73.1	75.6
Dev	-0.2	-0.3	*	2.8
Precip.	2.63	3.07	0.02	0.00
Dev	-0.93	-1.09	*	0.00
Cooling Degree Days	312	310	261	339

(Continued)

TABLE 3. Continued

	NORTHEAST	MIDWEST	N. CALIFORNIA	S. CALIFORNIA
AUGUST				
Temp	73.9	71.4	70.0	73.2
Dev	-0.1	-2.3	*	-0.7
Precip.	1.80	3.46	0.00	0.00
Dev	-2.30	-0.20	*	-0.09
Cooling Degree Days	284	208	166	259
SEPTEMBER				
Temp	69.2	67.5	65.3	70.0
Dev	2.0	1.3	*	-2.1
Precip.	3.29	2.92	0.28	0.24
Dev	-0.22	-0.28	*	0.08
Cooling Degree Days	157	174	58	156
OCTOBER				
Temp	58.3	55.5	59.9	67.4
Dev	1.6	0.8	*	-0.1
Precip.	0.93	5.54	0.90	0.14
Dev	-2.05	2.97	*	-0.01
Cooling Degree Days	14	4	31	98
NOVEMBER				
Temp	50.1	40.3	49.5	58.1
Dev	3.7	-0.4	*	-3.1
Precip.	6.68	7.63	3.67	4.21
Dev	2.95	5.49	*	2.85
Cooling Degree Days	0	0	0	0
DECEMBER				
Temp	34.0	19.5	42.5	57.7
Dev	-1.7l	-9.4	*	1.6
Precip.	0.87	1.52	2.67	0.33
Dev	-2.75	-0.90	*	-1.25
Cooling Degree Days	0	0	0	0
ANNUAL				
Temp	54.6	49.8	58.6	63.7
Dev	1.4	-0.8	*	-0.2
Precip.	33.01	40.57	14.23	8.23
Dev	-8.75	5.06	*	-3.31
Total Cooling Degree Days	947	961	829	1054
Seasonal Norm	886	955		1091

* Data not published for this weather station.
** Data reported in degrees farenheit and inches of precipitation as published.
*** Deviation from long term average for temperature or precipitation.

TABLE 4. LANDFILL CHARACTERISTICS

Characteristic	Northeast site	Midwest site	N. California site	S. California site
Year Start Fill	1974	1969	1975	1966
Completion Year	1983	1983	1983	1981
Year Start Recovery	1983	1983	1983	1984
Waste Type	Residential and Commercial	70% Residential 25% Commercial 5% Other	50% Residential 40% Commercial 10% Other	Municipal and Bldg. Rubble
Waste Amount in million metric tons	1.8	7.3-8.2	4.5	10.9
Av. Depth of Fill	36 m	15 m	23 m	Canyon to 49 m
Area of Fill (hectares) 54.6 h	12.1 h		36.4 h	37.2 h
Portion Tapped	50%	100%	75%	100%
Daily Cover	Sandy Local Soil	Local clay	Borrowed adjacent to site	Sandy Local soil taken from site
Cap	None	Blue Clay	Clay barrier around site	No Cap - One more lift to be added
Leachate Collection	Yes	No	No	No
LFG/Day of Sample	61,100 m^3	95,600 m^3	16,700 m^3	84,900 m^3
Condensate:				
Liters per Day	Unknown	4,250	2,700	5,700-7,500
Organic Phase		about 0.5%	about 0.5%	about 0.5%
Condensate pH	7.57	4.86	4.60	4.82
Condensate Fate	Treat and sewer with leachate	Burn hydrocarbon Treat & sewer H_2O	Sell hydrocarbon Treat & sewer H_2O	Sell hydrocarbon Treat and sewer H_2O
G.W. Depth	7.6-9.8 m		0-1.5 m	
G.W. Character	Lightly Saline		Lightly Saline	

The Southern California site is a closed site that accepted municipal trash and building rubble while active. It is a canyon fill covering about 55 hectares (135 acres) at depths as great as 49 meters. It has been fully developed as a gas production facility and collects LFG with a methane content of 54 percent. The operation produces about 5,700 to 7,500 liters of condensate per day consisting of about 0.5 percent hydrocarbon phase. The hydrocarbon is sold and the aqueous phase is treated and sewered.

The amount of condensate collected from the four sites varies from about 2700 to 7,500 liters per day. There is no apparent correlation between climate and condensate volume. The warm, dry Southern California site produces up to 7,500 liters per day from about 85,000 cubic meters of LFG, while the cool, moist midwestern site produces only about 4,200 liters per day from over 85,000 cubic meters of LFG.

Table 5 presents operating data from each of the four LFG collection systems taken at the time of sampling. Data include gas temperature, composition, and average BTU content. The control system in the Northeast is operated at a vacuum to ensure the capture of methane before it migrates off the site. Since the system is overdrawn to prevent migration, there is some air intrusion. As shown, the oxygen content is 8 percent and methane content is 22 percent. Consequently both aerobic and anaerobic regions probably exist within the fill.

Gas temperatures were measured on the inlet side of the vacuum pumping equipment at each site. It ranged from 17 degrees C at the Northern California gas production site to 36.7 degrees C at the migration control site. The gas temperatures are due to the interaction of fill temperatures and length of the piping in the collection system where cooling can occur. There were no fill temperatures available but the higher oxygen content at the control site may account for the increased gas temperature that may result from increased oxidative metabolism by the decomposer organisms.

CONDENSATE CHARACTERISTICS

In the three production sites, LFG condensate separates into two phases, a large aqueous phase with a small floating organic (hydrocarbon) phase. In all cases the phases are handled separately by the operators. At the Northeast control site an oily film was observed on the water that was sampled but it was of insufficient quantity to analyze separately for the hydrocarbon phase. At the Midwest site two phases were produced but sampling access was provided only to the aqueous phase by the site operator. Both aqueous and organic phases were sampled at the two California sites with the organic phase comprising approximately 0.5 percent of the condensate volume.

Table 6 presents condensate analytical results for the typical wastewater parameters, hazardous characteristics, and priority metals, as described in the QAPP. These results suggest that both the aqueous and hydrocarbon phases of the condensate are much stronger than normal domestic sewage but similar to

TABLE 5. LFG COLLECTION SYSTEM OPERATING DATA

	NORTHEAST	MIDWEST	N. CALIFORNIA	S. CALIFORNIA
Date	10/6/86	10/24/86	01/19/87	01/29/87
Time	2:00 pm	11:30 am	12:30 pm	10:50 am
Vacuum	30 mm Hg	94 mm Hg	89 mm Hg	221 mm Hg
Air Temp	17° C		12° C	21° C
Gas Composition:				
CO_2	14%	32.64%	39.55%	40.87%
O_2	8%	--	0.05%	--
CH_4	22%	63.35%	58.95%	54.26%
H_2	--	0.06%	0.25%	0.28%
Air(N_2 + O_2)	--	3.95%	--	4.87%
H_2S	--	17-19 ppm	47-52 ppm	30-40 ppm
N_2	--	--	1.91%	--
Avg. BTU/m^3	--	20,659	21,101	19,494
Gas Temperature at Sampling Port	37° C	23° C	17-18° C	29-32° C

TABLE 6. ANALYSIS OF LFG CONDENSATE FROM FOUR LANDFILLS: WASTEWATER PARAMETERS, HAZARDOUS CHARACTERISTICS, AND METALS

Measured parameter	Site/ Sample * NE H_2O	MW H_2O	NC H_2O	NC Organic	SC H_2O	SC Organic
WASTEWATER (mg/l): (typical strengths)+						
BOD (100 to 500 mg/l)	4000	7560	6100	17500	6000	15600
COD (250 to 1000 mg/l)	1042	1042	10200	23200	10200	30500
TOC (100 to 300 mg/l)	94	1003	18500	23500	4900	10200
NO3-N	0.73	<0.1	0.73	**	1.21	**
HAZARDOUS CHARACTERISTICS:						
Ignitability:	>60C	>60C	55C	50C	>60C	40C
Corrosivity (pH):	7.57	4.86	4.60	4.21	4.82	5.03
Reactivity (mg/l):						
CN	<0.05	<0.05	<0.20	<0.20	<0.20	<0.20
SO3	<0.10	<0.10	1.10	**	**	**
EP III Toxicity (ug/l):						
Silver	<0.006					
Beryllium	<0.005	<0.5%		<0.5%		<0.5%
Cadmium	<0.003	Solids		Solids		Solids
Chromium	<0.005					
Lead	<0.050					
Mercury	<0.002					
Selenium	<0.020					
PRIORITY METALS (ug/l):						
Silver	<0.006	<0.006	<0.006	<0.090	<0.006	<0.020
Beryllium	<0.005	<0.005	<0.005	<0.075	<0.005	<0.050
Cadmium	<0.003	<0.003	<0.003	<0.050	<0.003	<0.030
Chromium	<0.005	<0.005	<0.005	<0.075	<0.005	<0.050
Lead	<0.050	<0.050	<0.050	<0.075	<0.050	<0.075
Mercury	<0.002	<0.002	<0.002	<0.030	<0.002	<0.200
Selenium	<0.020	<0.020	<0.020	<0.300	<0.020	<0.020

* Abbreviations for sample sites: NE= Northeast, MW= Midwest, NC= Northern California, and SC= Southern California.

** Not analyzed.

\+ Derived from Metcalf and Eddy, 1974.

leachate for the wastewater parameters (Metcalf and Eddy, Inc., 1972; Walsh and Stamm, 1986) and thus, it may be treated as leachate at sites with a leachate treatment system.

The organic phase is composed of a matrix of straight chain hydrocarbons and may be sold to petroleum refiners and incorporated into the feed stock of the refinery. If no market is available, it may be disposed of by high temperature incineration. The handling and disposal options for either phase are restricted if the material is considered hazardous.

The samples from the four sites are compared on the basis of the four standard EPA hazardous waste characteristics below:

Ignitability

Of six condensate samples analyzed (four aqueous and two organic), three were ignitable. Both of the organic phase samples from California are ignitable. In addition, the Northern California aqueous sample was also ignitable at just under 60 degrees C (140 degrees F). Three historic sites reported ignitability tests, and one of those samples proved to be ignitable.

Corrosivity

The migration control system produced as slightly alkaline liquid (pH 7.6) while the three production systems all produced acidic condensate ranging from pH4.21 to 5.03 (Table 6). None have a pH low enough to be considered hazardous on the basis of corrosivity. Also none of the historical data (Tables 1 and 2) show condensate pH levels low enough to be considered hazardous.

Reactivity

No condensate samples were hazardous on the basis of reactivity. None of the samples have cyanide levels above detection limits. One of three samples has detectable sulfides. However, the samples are outside the pH range to evolve hazardous gas.

TCLP Toxicity Test

Recently, EPA has proposed to amend the EP Toxicity Test replacing the old leaching procedure with the new Toxicity Characteristics Leaching Procedure (FR V.51, 114. June 13, 1986). Part of this proposal includes expanding the list of toxic compounds from 14 to 52. The condensate analytical results were compared to this proposed list.

The samples were analyzed for pesticides, PCBs, and priority pollutant metals and organic compounds. No pesticides, PCBs, or priority pollutant metals wer detected in any samples. One sample (the control system) had more than 0.5 percent solids so the leaching procedure was used.

The organic constituents in the condensate samples were analyzed in three major groups for each phase sampled (4 aqueous and 2 hydrocarbon): the priority pollutant volatile organic compounds (Table 7), the priority pollutant base/neutral and acid extractable compounds (Table 8), and other organic compounds. These latter compounds were detected by GC/MS techniques but not quantified. The compounds were identified by computer match of their mass spectra to a library of 40,000 compounds (Table 9). In addition the samples were analyzed for pesticides and PCBs but neither was detected.

LFG condensate contains a complex mixture of substances and the matrix of the organic phase makes it difficult to prepare it for analysis. As a result of the dilutions necessary to analyze the organic fraction by GC/MS, low levels of compounds detected in the aqueous phase may not have been detected in the organic phase. Since condensate is a two-phase system, one would expect all substances in solution to distribute themselves in the two phases based on their respective oil/water partition coefficients.

A total of 94 organic compounds was identified, 49 of which are priority pollutant compounds. Eleven compounds were found in every condensate sample in either the aqueous or organic phase: benzene, toluene, phenol, ethyl benzene, benzyl alcohol, bis (2-chloroisopropyl) ether, bis (2- ethylhexyl) phthalate, naphthalene, N-nitrosodimethylamine, 2,4-dimethylphenol, and 4-methylphenol. Fifteen compounds in the condensate samples are on the TCLP Toxicity List. These are listed in Tables 10 and 11, along with their occurrence in each of the two phases (aqueous and organic phase) and the proposed regulatory level. Eight of the compounds were found to exceed proposed regulatory levels in the organic phase, three in both the organic and aqueous phases, and two in only the aqueous phase.

These compounds condense out of raw landfill gas (LFG). A literature review by SCS Engineers (October 6,1986) produced a list of 126 trace organic compounds found in LFG. From these, a list of 16 "typical" trace constituents was developed. Ten of these 16 compounds are also found in the condensate samples from the four landfills. Five of the 16 "typical" trace constituents are on the proposed TCLP Toxicity Test list. The six gaseous trace constituents not found in the condensate tend to be compounds with low vapor pressure not likely to condense in the LFG recovery environment.

It is uncertain from where the organic trace constituents originate. Many of them can be attributed to household hazardous wastes such as household cleaners, hairspray cans, paint cans, and other consumer products. Another contributing source could be small quantities of commercial waste such as discarded filters from dry cleaners, which contain tetrachlorethylene, and discarded paints and solvents from auto body shops. Many municipal landfills accept or receive a moderate amount of commercial/industrial wastes. The high variability in the commercial development from one region to another makes it very difficult to compare analytical results of condensate from various landfills.

TABLE 7. ANALYSIS OF LFG CONDENSATE FROM FOUR LANDFILLS: VOLATILE ORGANIC COMPOUNDS (ug/l)+

	Site/ Sample										
Measured parameter	NE-AQU 4351	NE-AQU 4355	MW-AQU 924	MW-AQU 925	NC-AQU 938	NC-AQU 938-Sp	NC-AQU 938-SpDu	NC-ORG 939	SC-AQU 988	SC-ORG 971	DETECTION LIMITS
Dilution Factor	1:20	1:1	1:5	1:20	1:10	1:10	1:10	1:20000	1:20	1:10000	1:1
Acetone	266	493	2000	2670	11300	11800	12200	357000	9420		1.0
Benzene	*	61	58	81	30	*	*	6800	*	31400	0.5
2-Butanone(MEK)	98		2440		9940	10900	11400		8100		1.0
Carbon Tetrachloride					129	122	58				1.0
Chlorobenzene	*		*	*	*					73700	1.0
Chloroform	*		*	*				33600			1.0
1,1-Dichloroethane		*	*	*	*						1.0
1,2-Dichloroethane		*	*		75	69	31				1.0
trans-1,2-Dichloroethylene	*	31	360	286	62	70	69			30800	1.0
1,2-Dichloropropane			*	28							1.0
Ethyl Benzene	*	41	704	860	1270	1530	1450	1140000	62	1590000	1.0
2-Hexanone	*	*	32	32	1920	2170	2130				1.0
Methylene Chloride	387		86	279	75	48		330000	192	156000	1.0
4-Methyl-2-Pentanone(MIK)	*	*	426	527	1850	2090	2050		1990	283000	1.0
Tetrachloroethylene			260	222	33	46	38	43600		184000	1.0
Toluene	26	47	618	2290	471	479	454	231000	205	1880000	1.0
1,1,1-Trichloroethane			*	*	144	134	64		140	169000	1.0
Trichloroethylene		*	49	62	*	*	34	435000		47600	1.0
o-Xylene		*	75	316	3260	3470	3270	2860000	235	2860000	1.0

Abbreviations: NE-AQU= Northeast site, aqueous phase; MW-AQU= Midwest site, aqueous phase; NC-ORG= Northern California site, organic phase; SC-AQU= Southern California site, aqueous phase. D= duplicate sample; Sp= spiked sample; SpDp= spiked duplicate sample.

+ Analytical values listed are the difference between the measured value and the field blank value.
* Compound detected at levels below 25 ug/liter, the lower limit for quantification.

TABLE 8. ANALYSIS OF LFG CONDENSATE FROM FOUR LANDFILLS: BASE/NEUTRAL AND ACID EXTRACTABLE FRACTIONS (ug/l)*

	Site/ Sample									
Measured parameter	NE-AQU 4356	NE-AQU. 4356-D	MW-AQU 918	MW-AQU 918-D	NC-AQU 965	NC-ORG** 966	SC-AQU 982	SC-AQU 982-D	SC-ORG** 983	DETECTION LIMITS
Dilution Factor	1:1	1:1	1:1	1:1	1:20	1:1.E+6	1:100	1:100	1:1.E+6	1:1
BASE/NEUTRAL FRACTION:										
Acenaphthene	*	*	108	129	*					1.0
Aniline			260	76						1.0
Anthracene			32	*						1.0
Benzoic Acid	*	*	53	*	392					1.0
Benzyl Alcohol	*	*	218	194	1670	36800000	3120		15600000	1.0
Bis (2-chloroethyl) ether			270	273	837	29400000			11900000	1.0
Bis (2-chloroethoxy) methane			66	67	198					1.0
Bis (2-chloroisopropyl) ether	*	*	81	22	1230		423	361		1.0
Bis(2-Ethylhexyl)phthalate	*	*	*	*			506	316		1.0
4-Chloroaniline			*	*				257		1.0
Dibenzofuran	*	*	57	55						1.0
Di-n-Butylphthalate	*	*	*	*				64		1.0
Di-n-Octylphthalate							58	27		1.0
1,2-Dichlorobenzene			65		27	1030000			452000	1.0
1,3-Dichlorobenzene	*	*	70		334	1040000			453000	1.0
1,4-Dichlorobenzene			65		329	1020000			444000	1.0
Diethylphthalate	*	*	50	37						1.0
Fluorene	*	*	74	61						1.0
Isophorone	*	*	113	104	68					1.0
2-Methylnaphthylene	*	*	139	199						1.0
Naphthalene	41	36	65	76	@6090		121	127		1.0
Nitrobenzene	52		*	*	64					1.0
N-Nitrosodimethylamine		*	50	*	201		143			1.0
N-Nitrosodi-n-Propylamine	45	249	1580	934						1.0
Phenanthrene			32	*						
ACID FRACTION:										
2,4-Dimethylphenol	44	60	94	86	246		843	290		5.0
2-Methylphenol			140	124						1.0
4-Methylphenol	80	175	136	131	4250		6110	203		1.0
2-Nitrophenol			*		2760					1.0
Phenol	92	127	210	153	121		4930	3570		1.0

Abbreviations: Same as Table 7.

\+ Analytical values listed are the difference between the measured value and the field blank value.

* Compound detected at levels below 25 ug/liter, the lower limit for quantification.

** The lack of detection of low level organics in the hydrocarbon phase may be due to the dilution necessary for analysis of this concentrated material using GC/MS techniques.

@ Compound found during library search. Concentration estimated due to lack of machine calibration.

TABLE 9. LFG CONDENSATE ANALYTICAL DATA: COMPOUNDS NOT ON THE PRIORITY POLLUTANT LIST *

	SITE					
	Northeast	Midwest	N. California		S. California	
Compound	Aqueous Sample	Aqueous Sample	Aqueous Sample	Organic** Sample	Aqueous Sample	Organic Sample
Acetic Acid, ethyl ester		y				
Alpha - Terpineol	y	y	y		y	
1-Butanol		y	y			
2-Butanol		y	y			
1,1-Bis(dodecycloxy)hexadecane		y				
Butanoic Acid	y				y	
Butanoic Acid, pentyl ester		y				
Butanoic Acid, propyl ester		y				
2-Butoxyethanol	y	y				
Camphor	y		y		y	
1,3,5-Cycloheptatriene		y				
Cyclohexanol	y	y				
Decane		y	y	y		y
Dodecane		y				
2-Ethylhexanoic Acid	y				y	
Hexanoic Acid	y	y			y	
Hexanoic Acid, hexyl ester		y				
1-Hexanol		y				
d-Limonene		y				
Nonanoic Acid	y					
Octanoic Acid	y					
9-Octadecanamide	y					
Pentadecane		y				
2-Propanol		y	y			
Tetradecane		y				
Tridecane		y				
2,5,6-Trimethyldecane		y				
2,6,11-Trimethyldodecane		y				
Undecane		y	y	y		y
Tetrahydrothiophene			y			
1,8-Cincole			y	y	y	y
4-methyl-1-(1-methyl ethyl)-3-Cyclohexen-1-ol			y		y	
2,6-Dimethyl Nonane				y		
Methyl (1-methylethyl) benzene				y		
Limonene				y		y
2,2,5-Trimethylhexane				y		
3,6-Dimethyl Undecane				y		
3 methyl Butanoic Acid					y	
Nonane						y
Alpha - Pinene			y	y		y
2,6,7-Trimethyl decane						y
1,3,dimethyl benzene						y
1ethyl-2-methyl benzene						y
Ethanol			y			
4-Carene				y		y
Alpha - Pineol						y

y = Found

* These compounds were detected and identified by GC/MS library search of 40,000 compound mass spectra. Listed arethe best matches of analyte spectra to library spectra. Accurate concentrations are not available for non-priority pollutants since the GC/MS was calibrated for the priority pollutants.

** The lack of detection of low level organics in the hydrocarbon phase may be due to the dilution necessary for analysis of this concentrated material using GC/MS techniques.

TABLE 10. MAJOR COMPOUNDS FOUND IN CONDENSATE: VOCs*

Compound	Presence		Regulatory Level+	Regulatory Level Exceeded	
	Aqueous	Organic	(mg/liter)	Aqueous	Organic
1. Benzene	x	x	0.07	x	x
2. Toluene	x	x	14.4		x
3. Methylene chloride	x	x	8.6		x
4. Trichloroethylene	x	x	0.07		x
5. 2-Butanone (MEK)	x		7.2	x	
6. Chlorobenzene	x#	x	1.4		x
7. Tetrachloroethylene	x	x	0.1	x	x
8. 1,1,1-Trichloroethane	x	x	30		x
9. Chloroform	x#	x	0.07		x
10. Carbon tetrachloride	x		0.07	x	
11. Ethyl benzene	x	x	NA		
12. Acetone	x	x	NA		
13. Methyl isobutyl ketone	x	x	NA		
14. o-Xylene	x	x	NA		
15. 2-Hexanone	x	x	NA		
16. Trans-1,2-dichloroethylene	x	x	NA		
17. 1,1-Dichloroethane	x		NA		

* All compounds shown are priority pollutants detected in at least 50 percent of the samples taken, or exceeding a regulatory level, in the VOC fraction.

\+ Regulatory level according to proposed TCLP Toxicity List in the June 13, 1986 Federal Register.

\# Detected, but at levels too low to reliably quantify.

NA No regulatory level proposed.

TABLE 11. MAJOR COMPOUNDS FOUND IN CONDENSATE: ACID AND BASE/NEUTRALS*

Compound	Presence		Regulatory Level+	Regulatory Level Exceeded	
	Aqueous	Organic	(mg/liter)	Aqueous	Organic
1. Phenol	x		14.4		
2. 1,2-Dichlorobenzene	x	x	4.3		x
3. 1,4-Dichlorobenzene	x	x	10.8		x
4. Nitrobenzene	x		0.13		
5. Bis(2-chloroisopropyl)ether	x	x	0.05	x	x
6. Benzyl alcohol	x	x	NA		
7. Bis(2-ethylhexyl)phthalate	x		NA		
8. Naphthalene	x		NA		
9. N-Nitrosodimethylamine	x		NA		
10. 2,4-Dimethylphenol	x		NA		
11. 4-Methylphenol	x		NA		
12. Acenaphthene	x		NA		
13. Benzoic acid	x		NA		
14. Di-n-Butylphthalate	x		NA		
15. Isophorone	x		NA		
16. Bis(2-chloroethyl)ether	x	x	NA		
17. 1,3-Dichlorobenzene	x	x	NA		

* Compounds shown based on priority pollutant analyses for the acid and base/neutral fractions, and detected in at least 50 percent of the samples taken, or exceeding a regulatory level.

\+ Regulatory level according to proposed TCLP Toxicity List in the June 13, 1986 Federal Register.

NA No regulatory level proposed.

Perhaps some of the organic compounds are generated by chemical reactions or biological activity within the landfill environment. Non-hazardous compounds may be converted to hazardous ones in the reducing atmosphere of the anaerobic landfill. The limited data from this study suggests that the difference between an oxidizing and reducing environment in a landfill may be very significant.

The protection system is normally overdrawn to prevent migration of methane off the landfill property. As a result, air is drawn into the waste creating a withdrawn gas mixture that is eight percent oxygen. Also at this site, the levels of trace organic compounds in the condensate are much lower than at the three production sites. The production sites are managed and operated to deliver maximum methane production and are thus kept as anaerobic as possible. The lack of organic compounds in the condensate from the aerobic site may result from their biodegradation in the aerobic conditions. Such a generalization from one site is speculative, but this is an area that should be studied further.

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

QUALITY OF DATA

Precision

Overall analytical precision for the samples was good with less than 25 percent of the precision calculations falling outside the range defined in the QAPP (Tables 12 and 13). This variation in sample repeatability can probably be attributed to complexity of sample matrix and difficulty in isolating the peaks due to marginal difference in elutriation times.

Accuracy

Accuracy of the instruments can be determined from spiked samples. Table 14 shows spike recoveries for sample 938 and a duplicate run. Spike recoveries ranged from 80.25 percent to 103.59 percent with an average spike recovery of 94.9 percent, which is considered very good.

Completeness

The work plan for this project proposed sampling four to eight sites from varied climatic regions. Both aqueous and organic phase would be sampled at each site. Each phase would be analyzed for the four hazardous waste characteristics, standard wastewater parameters, priority pollutants, and pesticides and PCBs. This full analysis was planned for the first two sites, with the extent of analysis at further sites to be determined based on the results from

TABLE 12. PRECISION OF ANALYTICAL TECHNIQUES: VOLATILE ORGANIC COMPOUNDS (ug/l)

Measured parameter	Site/ sample NC-AQU 938-Sp	NC-AQU 938-SpDu	Relative % Repeatability
(Dilution factor)	1:10	1:10	
Acetone	11800	12200	- 3.33
Benzene	*	*	
2-Butanone(MEK)	10900	11400	- 4.48
Carbon Tetrachloride	122	58	71.11
1,2-Dichloroethane	69	31	76.00
trans-1,2-Dichloroethylene	70	69	1.44
Ethyl Benzene	1530	1450	5.37
2-Hexanone	2170	2130	1.86
Methylene Chloride	48		200.00 @
4-Methyl-2-Pentanone(MIK)	2090	2050	1.93
Tetrachloroethylene	46	38	19.05
Toluene	476	454	5.36
1,1,1-Trichloroethane	134	64	70.71
Trichloroethylene	*(5)	34	-148.72 @
o-Xylene	3460	3270	5.65

Abbreviations: Same as Table 7
* Compound detected at levels too low to reliably quantify.
@ Falls outside defined QAPP limits.

TABLE 13. PRECISION ANALYSIS DATA FROM FOUR LANDFILLS: BASE/NEUTRAL AND ACID EXTRACTABLE FRACTIONS (ug/l)

Measured parameter	Site/Sample NE-AQU 4356	NE-AQU. 4356-D	Precision (%)	MW-AQU 918	MW-AQU 918-D	Precision (%)	SC-AQU 982	SC-AQU 982-D	Precision (%)
Dilution Factor	1:1	1:1		1:1	1:1		1:100	1:100	
BASE/NEUTRAL FRACTION:									
Acenaphthene	*	*		108	129	- 17.72			
Aniline				260	76	109.52			
Anthracene				32	*(21)	41.51			
Benzoic Acid	*	*		53	*(18)	98.59			
Benzyl Alcohol	*	*		218	194	11.65	3123		200.00 @
Bis (2-chloroethyl) ether				270	273	- 1.15			
Bis (2-chloroethoxy) methane				66	67	- 1.50			
Bis (2-chloroisopropyl) ether	*	*		81	22	114.56	423	361	15.82
Bis(2-Ethylhexyl)phthalate	*	*		*	*		506	316	46.23
4-Chloroaniline				*	*			257	-200.00 @
Dibenzofuran	*	*		57	55	3.57			
Di-n-Butylphthalate	*	*		*	*			64	-200.00 @
Di-n-Octylphthalate							58	27	72.94
1,2-Dichlorobenzene				65		200.00 @			
1,3-Dichlorobenzene	*	*		70		200.00 @			
1,4-Dichlorobenzene				65		200.00 @			
Diethylphthalate	*	*		50	37	29.89			
Fluorene	*	*		74	61	19.26			
Isophorone	*	*		113	104	8.30			
2-Methylnaphthylene	*	*		139	199	- 35.50			
Naphthalene	41	36	12.99	65	76	- 15.60	121	127	- 4.84
Nitrobenzene	52		200.00 @	*	*				
N-Nitrosodimethylamine		*		50	*(4)	170.37 @	143		200.00 @
N-Nitrosodi-n-Propylamine	45	249	-138.78 @	1583	934	51.57			
Phenanthrene				32	*(21)	41.51			
ACID FRACTION:									
2,4-Dimethylphenol	44	60	- 30.76	94	86	8.88	843	290	97.62
2-Methylphenol				140	124	12.12			
4-Methylphenol	80	175	- 74.51 @	136	131	3.75	6111	203	187.14 @
2-Nitrophenol				*					
Phenol	92	127	- 31.96	210	153	31.41	4929	3569	32.01

Abbreviations: Same as table 7.
* Compound detected at levels too low to reliably quantify.
@ Falls outside defined QAPP limits.

TABLE 14. Spike Recoveries

Sample No. 938 (Volatiles)

Spiked Compound	Amount of spike (ug)	Amount in sample (ug)	Amount recovered (ug)	Percent Recovery
1,1-Dichloroethylene	500	--	401.26	80.25
Trichloroethylene	500	16.66	506.50	98.03
Chlorobenzene	500	9.03	492.04	96.66
Benzene	500	31.01	509.81	96.01
Toluene	500	474.12	981.39	100.75

Sample No. 938 (Volatiles), Spike Duplicate

Spiked Compound	Amount of spike (ug)	Amount in sample (ug)	Amount recovered (ug)	Percent Recovery
1,1-Dichloroethylene	500	--	421.70	84 34
Trichloroethylene	500	16.66	535.23	103.59
Chlorobenzene	500	9.03	480.37	94.37
Benzene	500	31.01	515.14	97.01
Toluene	500	474.12	956.55	98.25

the first two sites. Table 15 below outlines those samples planned and compares them to those samples successfully analyzed. Four sites were chosen, two from cold and two from warm regions. The site owner did not give access to the organic phase at the Midwest site. Although not originally planned, the organic phase was analyzed for wastewater parameters. Also, many non-priority pollutant organic compounds were identified by GC/MS library search which was not part of the original plan. This was done as a result of the complexity of matrices discovered at the first two sites so that ultimately more samples were successfully analyzed than originally planned.

Representativeness

Condensate samples were considered sufficiently representative. All condensate samples were collected from the same relative location in the LFG collection system. Samples were taken from large collection tanks or low points in the collector piping where sufficient condensate volume had accumulated.

TABLE 15. SUMMARY OF CONDENSATE SAMPLING COMPLETENESS

Test	Planned Analyses: Aqueous phase	Planned Analyses: Organic phase	Samples actually analyzed: NE Site Aq	NE Site Or	MW Site Aq	MW Site Or	NC Site Aq	NC Site Or	SC Site Aq	SC Site Or
Ignitability	y	x	x	none	x	none	x	x	x	x
Corrosivity	y	x	x	present	x	sampled	x	x	x	x
Reactivity	y	x	x	*	x	-	x	x	x	x
EP III Toxicity	y	x	x	*	x	-	x	x	x	x
P.P. A/B/N	y	x	x	*	x	-	x	x	x	x
P.P. Volatiles	y	x	x	*	x	-	x	x	x	x
Pesticides/PCBs	y	x	x	*	x	-	x	x	x	x
BOD	y	no	x		x		x	+	x	+
COD	y	no	x		x		x	+	x	+
TOC	y	no	x		x		x	+	x	+
SO_4	y	no	x		x		x	+	x	+
Cl-	y	no	x		x		x	+	x	+
NO_3	y	no	x		x		x	+	x	+
Other Organics (non-priority pollutants)	no	no	+		+		+	+	+	+

y Sample planned.
no Sample not planned.
x Sample planned and collected/analyzed.
- Sample planned but not collected/analyzed.
+ Sample not originally planned but collected and analyzed.
* Sample planned but absent from the LFG collection system.

Comparability

In samples where organic and aqueous fractions were analyzed separately, caution should be exercised when attempting comparison between the two phases. The organic fractions were diluted (1:1.0E+6) due to high concentrations of organic compounds. These dilutions may have caused lower level compounds to go below detection limits.

CHANGES TO QAPP

No deviations were made from the QAPP.

LIMITATIONS ON USE OF DATA

Compounds detected below 25 ug/l are not quantified in the tables. Concentrations below this level were considered inaccurate according to instrument limitations such as noise and poor resolution of densely packed peaks. Detection limits for compounds varied with the concentration of the sample and due to the high variability of constituent concentrations in samples from the various sites, any concentration detected below 25 ug/l was not quantified.

Samples from various sites were analyzed at different dilution levels. These dilution factors are listed in the table to allow calculation of sample detection limits by multiplying the standard detection limit by the sample dilution factor.

Many non-priority pollutants were detected through the library search of 40,000 compounds. The quantities of these pollutants could not be reported since they were outside the calibration curve. Table 9 lists the compounds detected at different sites which are not on the priority pollutant list.

QA/QC PROBLEMS

High concentrations of constituents in the oily hydrocarbon phase of condensate created problems in accurately quantifying some pollutants due to the necessity for large dilutions. Some low level compounds may have remained undetected.

Problems were encountered in the analysis of condensate samples for detection of pesticides due to high levels of sulfur. Sulfur compounds had masking effects on the first four minutes of chromatograms. Attempts to clean up the samples were unsuccessful. However, no pesticides or PCBs were detected in the eluent after the first four minutes that were masked.

REFERENCES

1. American Petroleum Institute, Literature Survey: Hydrocarbon Solubilities and Attenuation Mechanisms. API Publication No. 4414. 1985.

2. Bogardus, Ellen R. Gas Recovery: Will It Soon Be Required of All Landfill Owners? Waste Age, V16 (3): 79-82. 1985.

3. Emcon Associates. Methane Generation and Recovery from Landfills. Ann Arbor Science Publishers, Inc. Ann Arbor, Michigan. 1982.

4. Metcalf and Eddy, Inc. Wastewater Engineering: Collection, Treatment, Disposal. McGraw-Hill Book Co., New York. 1972.

5. SCS Engineers. Data Base for Landfill Gas Trace Constituents, Memorandum to Allen Geswein, U.S. Environmental Protection Agency, Land Disposal Branch, Office of Solid Waste. October 6, 1986.

6. SCS Engineers. Methane Production at Closed Landfills, Draft Report. Center for Environmental Management, Tufts University, Medford, Massachusetts, 58 pp. 1986.

7. Walsh, J. and J. Stamm. Pilot Scale Evaluation of Sludge Landfilling: Fourth Annual Report, EPA Contract No. 68-03-3220, U.S. Environmental Protection Agency, Cincinnati, Ohio, October 1986.

8. Waste Age, eds., Landfill Gas Survey, Waste Age, November 1985.